Nd-Sr-Hf ISOTOPIC AND GEOCHRONOLOGIC STUDIES OF APOLLO 15 BASALTS

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We have analyzed the Nd, Sr, and Hf isotopic composition of a set of mare basalts from the Apollo 15 collection to elucidate their ages and sources. Olivine-normative basalt *15016* appears to have an initial $^{176}Hf/^{177}Hf$ that is unique to other Apollo 15 basalts. Quartz-normative basalt *15475* yields a 4-point Rb-Sr age of 3.43±0.15 Ga, a 3-point Sm-Nd age of 3.37±0.05 Ga, and initial Sr and Nd isotopic ratios similar to other quartz-normative basalts from the Apollo 15 collection, indicative of similar origins. Mineral separates and mechanical splits of picritic basalt *15385* do not yield a well-defined Sm-Nd age, but the data could be interpreted as defining an age of 3.54±0.22 Ga. The initial Hf isotopic composition of this rock is similar to other Apollo 15 basalts. This picritic basalt is best explained as an olivine-normative basalt with ~30% accumulated olivine.

GEOCHRONOLOGY -- Much geochronologic work has been performed on olivine-normative basalts from the Apollo 15 landing site, but little has been reported from either the quartz-normative basalts or picritic basalts. We have separated minerals from one quartz-normative basalt, *15475*, and a picritic basalt, *15385*, in an attempt to ascertain their ages and isotopic compositions. All Rb-Sr ages from the literature have been recalculated assuming a decay constant of 1.402×10^{-11} yr^{-1} for ^{87}Rb, Nd isotopic ratios are referenced to a $^{146}Nd/^{144}Nd$ of 0.7219, and all ages are calculated using the program of Ludwig [1].

Quartz-normative basalt *15475* yields a 4-point Rb-Sr isochron (Fig. 1) corresponding to an age of 3.43±0.15 Ga (MSWD = 7.15) with an $^{87}Sr/^{86}Sr_i$ = 0.699365±30. A 3-point Sm-Nd isochron (Fig. 2) corresponds to an age of 3.37±0.05 Ga (MSWD = 1.28) and overlaps the age for the Rb-Sr isochron, although at higher precision. This sample is slightly older than olivine-normative basalts from the Apollo 15 landing site (3.15±0.08 to 3.29±0.06 Ga; [2,3], but identical in age to the unique basalt 15388 (3.36±0.04 Ga [4]). The initial ε_{Nd} value for this sample (+1.2±1.0) is slightly lower than that for other quartz-normative basalts (ε_{Nd} = +2.0±0.4 to +2.6±0.4 at 3.25 Ga; [5]), but well within analytical error. The initial $^{87}Sr/^{86}Sr$ value for *15475* is similar to that of the olivine-normative basalts (0.69934±5; [3]), but slightly higher than the unique basalt 15388 (0.699285±5; [4]).

Mineral fractions separated from the picritic basalt *15385* do not yield a unique, unequivocal age, but lie about an errorchron coresponding to a rough "age" of 3.76±1.01 Ga (MSWD = 81.9)(Fig. 3). Assuming the Sm-Nd systematics of the pyroxene separate have been disturbed relative to the other splits, the remaining four separates, along with the whole-rock split, suggest an age of 4.23±0.40 Ga [MSWD = 8.92; $(\varepsilon_{Nd})_i$ = +1.4]. If this age is upheld by further isotopic studies, this would be the oldest basalt yet analyzed from the Apollo 15 landing site and one of the oldest analyzed from the Moon. In contrast, $^{40}Ar/^{39}Ar$ analyses have indicated a much younger age of 3.32±0.06 Ga [2] similar to other basalts at the Apollo 15 landing site. Assuming the whole-rock, magnetic, residue, and fine-grained separates were disturbed, plagioclase and pyroxene separates yield a two-point isochron with an age of 3.54±0.22Ga, in agreement with the $^{40}Ar/^{39}Ar$ age. Thus, the older age may be indicating Sm-Nd isotopic disturbance and may not represent a "true" age. For the present study, we will assume that the younger $^{40}Ar/^{39}Ar$ age is valid for picritic basalt *15385*. Obviously, further isotopic work on this and other picritic basalt samples from Apollo 15 are warranted.

Hf ISOTOPIC RESULTS -- We have investigated the Hf isotopic composition of two samples of Apollo 15 basalts using a multi-collector ICP-MS [6] and report the following preliminary results (measured $^{176}Hf/^{177}Hf$): *15016,177* = 0.282060±49; *15385,12* = 0.282333±33. Using Lu/Hf ratios from the literature as a rough estimate (*15016* = 0.1632 (avg. of [7, 8]); *15385* = 0.1318 [9]), the initial $^{176}Hf/^{177}Hf$ compositions can be calculated.

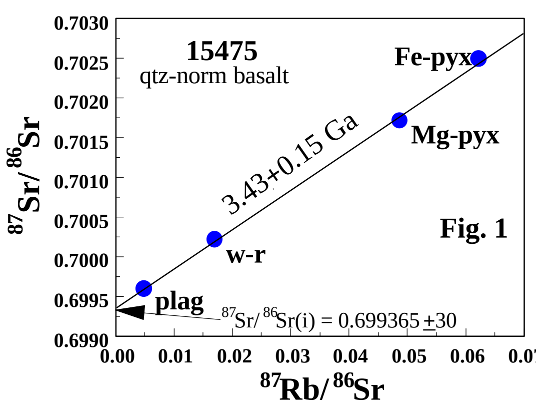

Fig. 1

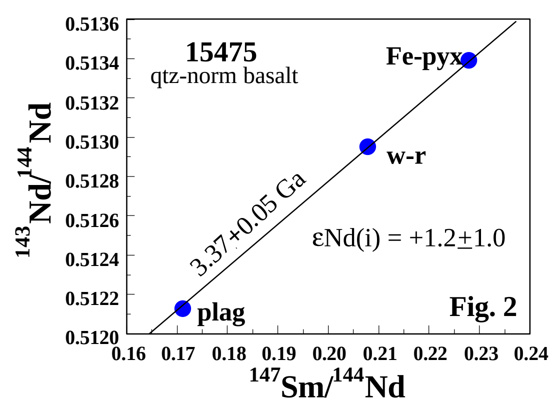

Fig. 2

Table 1: Nd and Sr Isotopic Composition of Whole-rock and Mineral Separates from Basalt 15475

Rock	wt.(mg)	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
15475-WR	11	2.61	7.59	0.2079	0.512950±10	0.518	88.2	0.0170	0.700218±13
15475-PL	11	1.25	4.42	0.1712	0.512126±10	0.508	301	0.00487	0.699596±13
15475-MgPyx	26					0.277	16.5	0.0487	0.701715±39
15475-FePyx	10	0.804	2.03	0.2280	0.513389±10	0.369	17.1	0.0623	0.702493±85

Unruh et al. [5] could not distinguish the Nd and Hf isotopic compositions of the sources for the quartz-normative and olivine-normative basalts. The $^{176}Hf/^{177}Hf$ composition of picritic basalt *15385* (0.28109 @3.32 Ga [2]) is indistinguishable from the other basalts collected along the Appenine Front [5], suggesting it was derived from a similar source. However, olivine-normative basalt *15016* either a) has a significantly lower initial $^{176}Hf/^{177}Hf$ composition (0.28082 @3.32 Ga [10]) than other Apollo 15 basalts (0.28104 to 0.28108), suggesting a different source; or b) it has a $^{176}Lu/^{177}Hf$ (0.01502) that is much lower than any other Apollo 15 basalt (0.01803 to 0.02179 [5]).

PETROGENESIS -- Quartz-normative basalt *15475* is similar in age and initial Nd and Sr isotopic composition to other basalts from this group and was probably derived from a similar source. Based upon major-element considerations, Rhodes and Hubbard [11] postulated that the picritic basalt, *15385*, could not be simply related to other Apollo 15 basalts by accumulation of olivine and/or pigeonite. They further stated that the REE abundances of the picritic basalt indicated that it must have come from a magma more evolved than that which was parental to other Apollo 15 mare basalts. However, our isotope dilution analyses of *15385* indicate that it has lowest Sm and Nd abundances of all Apollo 15 mare basalts and a factor of 3 lower than that reported by Rhodes and Hubbard [11]. The REE abundances for *15385* are comparable to those of other picritic basalts (15274,3, 15387, 15388) along the Apennine Front [12]. Thus, we concur with Ryder and Steele [12] that all four picritic basalts can be derived from the main trend of olivine-normative basalts by ~30% olivine accumulation.

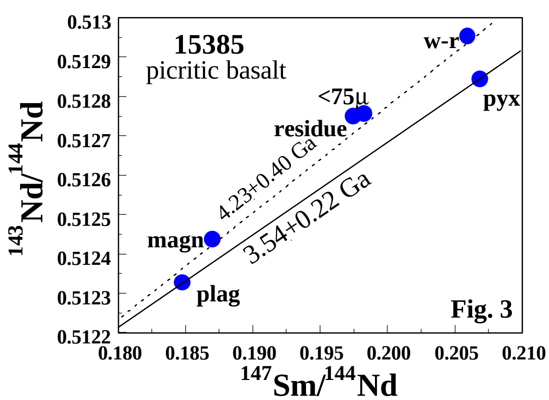

Table 2: Nd Isotopic Composition of Mineral Separates from 15385

Rock	wt. (mg)	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$
15385-WR	34	1.71	5.01	0.2059	0.512953±09
15385-PL	35	0.367	1.20	0.1848	0.512327±27
15385-Pyx	57	0.719	2.10	0.2069	0.512844±13
15385-Magn	9	7.60	24.6	0.1870	0.512437±12
15385-<75µ	43	2.19	6.68	0.1983	0.512756±13
15385-residue	31	2.55	7.81	0.1975	0.512749±09

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